# Apparent stability of GPS monumentation from long-running short baselines

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## Introduction

Long-running, short GPS baselines offer an insight into the error budget of GPS-based geophysical estimates inferred from continuous GPS coordinate time series. Any local seasonal or secular signals will also affect reference frame accuracy and, at co-located sites, may be interpreted as errors in instantaneous local site ties.

Here, we describe the results of an investigation into the apparent stability of 10 long-running short baselines. Satellite orbit and common geophysical/propagation errors are minimised in such short baselines, allowing an insight into local site effects (both GPS and geophysical).

## Methods

- Ten multi-year short baselines (<200m; Δh<10m) were identified from the IGS and other archives (Table 1).
- Only the period 2000-2007 was considered. Available data sets were further windowed so as to minimise the number of hardware changes, although some changes were unavoidable. Figure 1 shows the time periods considered for each baseline.
- All data were processed kinematically (30s sampling, 7° and 20° cut-offs) in Track (part of GAMIT/GLOBK). This avoids the potential for propagation of sub-daily signals that can occur in 24 h solutions.

| Baseline | Lat. (°) | Lon. (°) | Length (m) |
|---|---|---|---|
| **BOGO-BOGI** | 52.5 | 21.0 | 107.201 |
| **HERT-HERS** | 50.9 | 0.3 | 136.262 |
| **JOZE-JOZ2** | 52.1 | 21.0 | 84.284 |
| **MATE-MAT1** | 40.6 | 16.7 | 10.744 |
| **METS-METZ** | 60.2 | 24.4 | 1.054 |
| **OHI2-OHI3** | -63.3 | 302.1 | 2.976 |
| **PIN1-PIN2** | 33.6 | 243.5 | 50.275 |
| **TROM-TRO1** | 69.7 | 18.9 | 51.154 |
| **WTZR-WTZA** | 49.1 | 12.9 | 3.064 |
| **ZIMM-ZIMJ** | 46.9 | 7.5 | 14.184 |

**Table 1:** Baseline Information

| Baseline | | 7° (mm/yr) | 20° (mm/yr) |
|---|---|---|---|
| **BOGO-BOGI** | N | -0.08±0.03 | -0.08±0.03 |
| | E | -0.08±0.02 | -0.06±0.02 |
| | U | **0.32±0.03** | 0.04±0.04 |
| **HERT-HERS** | N | 0.04±0.07 | 0.06±0.08 |
| | E | **-0.27±0.08** | -0.24±0.07 |
| | U | **-0.80±0.10** | **-0.53±0.09** |
| **JOZE-JOZ2** | N | **-0.35±0.09** | **-0.37±0.08** |
| | E | -0.19±0.06 | -0.20±0.06 |
| | U | **0.29±0.09** | 0.04±0.09 |
| **MATE-MAT1** | N | -0.05±0.02 | -0.03±0.02 |
| | E | 0.04±0.02 | 0.13±0.02 |
| | U | **0.27±0.04** | 0.12±0.04 |
| **METS-METZ** | N | -0.01±0.03 | -0.05±0.03 |
| | E | -0.00±0.04 | -0.01±0.03 |
| | U | 0.05±0.03 | 0.10±0.03 |
| **PIN1-PIN2** | N | -0.04±0.06 | -0.04±0.04 |
| | E | 0.02±0.04 | 0.02±0.05 |
| | U | -0.03±0.04 | -0.04±0.06 |
| **WTZR-WTZA** | N | -0.16±0.02 | -0.13±0.01 |
| | E | 0.16±0.01 | 0.16±0.01 |
| | U | 0.17±0.02 | 0.22±0.01 |
| **ZIMM-ZIMJ** | N | **0.57±0.07** | **0.59±0.05** |
| | E | -0.22±0.06 | -0.21±0.07 |
| | U | -0.04±0.07 | -0.00±0.06 |

**Table 2:** Velocities, for time series >2.5 years

## Results

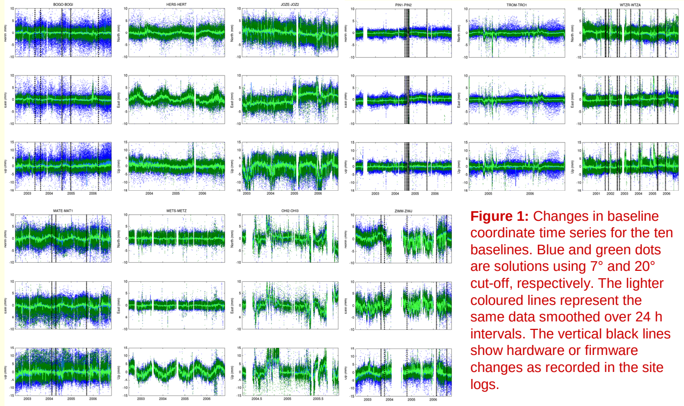

**Figure 1:** Changes in baseline coordinate time series for the ten baselines. Blue and green dots are solutions using 7° and 20° cut-off, respectively. The lighter coloured lines represent the same data smoothed over 24 h intervals. The vertical black lines show hardware or firmware changes as recorded in the site logs.

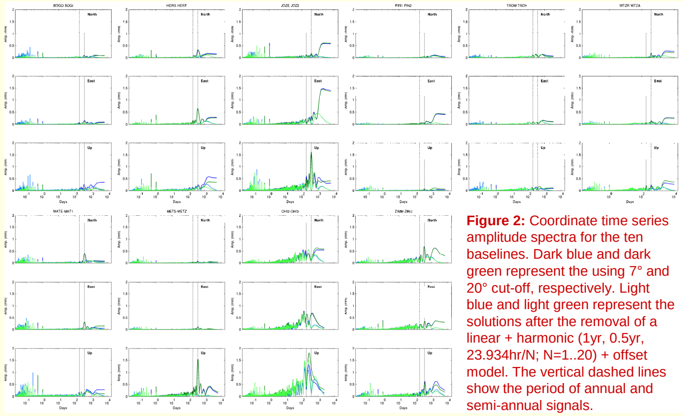

**Figure 2:** Coordinate time series amplitude spectra for the ten baselines. Dark blue and dark green represent the using 7° and 20° cut-off, respectively. Light blue and light green represent the solutions after the removal of a linear + harmonic (1yr, 0.5yr, 23.934hr/N; N=1..20) + offset model. The vertical dashed lines show the period of annual and semi-annual signals.

### Thermal Expansion

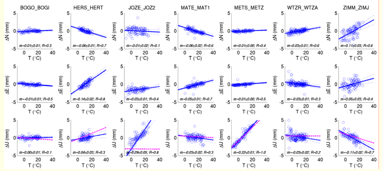

**Figure 3:** Regression between temperature (from RINEX met files) and coordinate component data, after smoothing over 30-days. Temperature data are only available at the sites shown. The dashed magenta line shows a predicted linear thermal expansion effect based on monument materials.

### Noise characteristics

| | SI | PL | WN | SI | PL | WN | SI | PL | WN |
|---|---|---|---|---|---|---|---|---|---|
| **Baseline** | **North** | | | **East** | | | **Vertical** | | |
| **BOGO-BOGI** | 1.25 | 0.72 | 0.08 | 0.95 | 0.44 | 0.04 | 0.88 | 0.97 | 0.00 |
| **HERT-HERS** | 0.85 | 0.77 | 0.00 | 1.16 | 1.38 | 0.06 | 0.72 | 1.45 | 0.00 |
| **JOZE-JOZ2** | 1.15 | 1.62 | 0.00 | 1.73 | 3.06 | 0.16 | 1.24 | 6.17 | 0.00 |
| **MATE-MAT1** | 0.93 | 0.90 | 0.00 | 0.90 | 0.77 | 0.00 | 1.23 | 1.62 | 0.41 |
| **METS-METZ** | 0.83 | 0.51 | 0.00 | 0.84 | 0.40 | 0.00 | 1.23 | 3.30 | 0.00 |
| **OHI2-OHI3** | 1.29 | 5.89 | 0.00 | 1.90 | 12.31 | 0.17 | 2.00 | 23.20 | 0.37 |
| **PIN1-PIN2** | 1.98 | 0.28 | 0.04 | 1.45 | 0.28 | 0.05 | 0.77 | 0.37 | 0.12 |
| **TROM-TRO1** | 1.54 | 1.67 | 0.00 | 1.12 | 0.92 | 0.00 | 1.28 | 2.53 | 0.00 |
| **WTZR-WTZA** | 0.99 | 0.94 | 0.00 | 1.07 | 0.67 | 0.00 | 1.35 | 3.61 | 0.00 |
| **ZIMM-ZIMJ** | 1.60 | 7.18 | 0.00 | 1.51 | 6.70 | 0.00 | 0.93 | 2.64 | 0.00 |

**Table 3:** Power-law noise results. SI (spectral index), PL (power law) and WN (White Noise, units mm).

## Discussion

Thermal expansion effects are unable to explain the observed baseline changes at seasonal timescales. Multipath represents one likely source of the observed seasonal signals. Insensitivity to elevation cut-off angle, however, would suggest a high elevation origin in this case. Antenna “imaging” is another possibility. The observed quasi-secular signals (Table 2) may be due to monument instability, but we also note that the GPS constellation is evolving and hence systematic errors will propagate differently as the geometry changes.

The flicker noise present in these time series is ~1-2 orders of magnitude smaller than in PPP solutions and hence local site effects are not dominant in global studies.

If these baseline motion results were representative of the ~300 currently active IGS sites, 180 would have annual signals >0.5 mm in at least one coordinate component, 150 would have linear rates > 0.25 mm/yr and almost all sites would have sub-daily signals >0.1 mm, each solely due to local site effects. Agreements with local tie survey data will be time-dependant.

## Conclusion

- Further work is required to understand and model the sources of the observed signals. Until then, geophysical estimates must be regarded as being potentially biased by signals with magnitudes up to those evident in Figure 1.
- Additional long-running short baselines are required. IGS station operators are encouraged to pursue this by installing a second monument.

## Acknowledgements

MAK is supported by a NERC research fellowship.
Tom Herring is thanked for ongoing Track support.